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(71) Applicant: MOTOROLA INC. [US/US]; 1303 East Algonquin Road, Schaumburg, IL 60196 (US).

(72) Inventors: MISSELE, Carl; 2297 Knollwood Drive, Elgin, IL 60123 (US). LECLAIR, Tim; 517 Pinon Creek Road, S.E., Albuquerque, NM 87123 (US).

(74) Agents: SONNENTAG, Richard, A. et al.; Motorola Inc., Intellectual Property Dept., 1303 East Algonquin Road, Schaumburg, IL 60196 (US).

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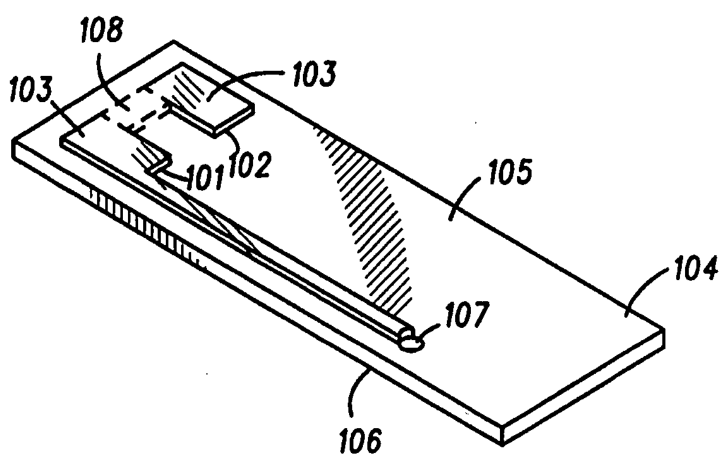
(57) Abstract

A circuit comprising a microstrip conductor (101, 102) is manufactured from silver having a protective layer (103) of copper. During manufacture, a ceramic substrate (104) is cleaned and a ground plane (106), and a through via (107) are printed onto the substrate (104) and fired. Next, silver microstrip conductors (101, 102) are deposited (screen printed) onto an upper surface (105) of the substrate (104). Finally, a copper layer (103) is deposited onto all silver surfaces via an electroless copper plating process.



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CIRCUIT COMPRISING MICROSTRIP CONDUCTOR AND METHOD FOR MAKING THE SAME

Field of the Invention

The present invention relates generally to circuits comprising microstrip conductors and, in particular, to fabrication of such circuits comprising microstrip conductors.

Background of the Invention

Circuits utilizing thick-film technology require low loss metals for producing microstrip conductors. A prior-art approach to fabricating such microstrip conductors has been to utilize Silver in their manufacture. However, because Silver is quite soluble in solder, the Silver must be protected from direct contact with solder when attaching circuit components with solder. One approach to protecting the Silver layer from direct contact with solder is to electroplate Copper over the Silver layer. In order to make this approach work, a technique is required whereby all Silver within the circuit needs to be electrically connected to the cathode of the electroplating bath during electroplating. This is usually accomplished by firstly electrically connecting all Silver that is to be electroplated, and secondly, connecting a small area of Silver to the cathode of the electroplating bath. The first step mentioned above is typically accomplished by creating temporary interconnecting conductive pathways to electrically connect all Silver that is to be electroplated, and then removing the interconnecting pathways after electroplating.

There are several methods of creating temporary interconnecting conductive pathways during the electroplating step. One such method is described in US Pat. No. 4,661,214 "Method and Apparatus for Electrically Disconnecting Conductors" by Young. This method utilizes conductive "islands" under a substrate which are initially conductive and

then rendered resistive by temperature treatment. Another, more common method for creating temporary electrical connection of isolated Silver is by creating a temporary interconnecting pathway with a polymer Silver conductor to the isolated Silver and applying a plating resist to the surface of the pathway to prevent Copper from being plated onto the pathway during the electroplating operation. After electroplating, the resist and the interconnects are chemically removed, leaving only Copper-protected Silver on the substrate.

The creation of temporary interconnecting conductive pathways in the manufacture of circuits utilizing microstrip conductors causes many problems. First, the creation of conductive pathways requires added process steps that increase the cost associated with their manufacture. Second, due to current density differences across the substrate during electroplating, the protective Copper layer usually has poor uniformity across the substrate. Finally, the electroplating process is environmentally unfriendly since chemicals (such as Copper Sulfate and Sulfuric Acid) utilized in the electroplating process are known to be harmful to the environment. Thus a method is needed for the creation of circuits comprising multi-layer microstrip conductors that eliminates the above-mentioned problems.

Brief Description of the Drawings

FIG. 1 is a circuit comprising Silver microstrip conductors having a protective layer of Copper.

FIG. 2 is a flow chart illustrating a prior-art method of manufacturing a circuit having Silver microstrip conductors.

FIG. 3 is a flow chart illustrating fabrication of a circuit having Silver microstrip conductors in accordance with the preferred embodiment of the present invention.

Detailed Description of the Drawings

Stated generally, a circuit comprising a microstrip conductor is manufactured from Silver having a protective layer of Copper. During the manufacture, a ceramic substrate is cleaned and a ground plane, and a through via are printed onto the substrate and fired. Next, Silver microstrips are deposited (screen printed) onto an upper surface of the substrate. Finally, a Copper layer is deposited onto all Silver surfaces via an electroless Copper plating process. The use of an electroless plating process to plate a protective layer of Copper onto microstrips eliminates the need for temporary interconnecting pathways. The elimination of such pathways reduces the cost associated with the manufacture of circuits utilizing microstrip conductors as well as reduces the amount of environmentally unfriendly chemicals utilized during circuit manufacture. Finally, because the deposition of the protective layer of Copper onto the microstrips is accomplished via an electroless plating process, the prior-art problems with current density/uniformity are eliminated, resulting in a more uniform layer of Copper.

The present invention encompasses a method for manufacturing a circuit having a microstrip conductor. The method comprises the steps of depositing a microstrip conductor onto a substrate and depositing a protective layer on the microstrip conductor via an electroless plating process.

An alternate embodiment of the present invention comprises a circuit comprising a substrate, and a microstrip conductor existing upon the substrate, and a protective layer existing on the microstrip conductor. In the preferred embodiment of the present invention the protective layer comprises a material that is deposited on the microstrip conductor via an electroless plating process.

A final embodiment of the present invention encompasses a method for manufacturing a circuit having a microstrip conductor. The

method comprises the steps of screen printing a ground plane and a through via onto a lower surface of a substrate, firing the ground plane, screen printing an acid resistant Silver microstrip conductor and a through via onto an upper surface of the substrate, firing the Silver microstrip conductor; and finally depositing, via an electroless plating process, a Copper layer onto the Silver microstrip conductor to produce a Silver microstrip conductor with a protective layer of Copper. In the preferred embodiment of the present invention the protective layer of Copper is deposited onto the microstrip conductor by, pre-cleaning the Silver microstrip conductor, utilizing an activator to increase plating speeds, and immersing the Silver microstrip conductor in an electroless plating bath.

FIG. 1 shows circuit 100 comprising Silver microstrip conductors 101 and 102 having protective layer of Copper 103. Circuit 100 comprises substrate 104 having upper surface 105, lower surface 106, and through via 107. In the preferred embodiment of the present invention lower surface 106 acts as a ground plane, with through via 107 serving to electrically connect microstrip 101 to ground plane 106. As discussed above, in order to electroplate Copper layer 103 over microstrips 101 and 102, microstrips 101 and 102 need to be electrically connected to the cathode of the electroplating bath during electroplating. In prior-art methods, this is accomplished by firstly creating temporary interconnecting conductive pathway 108, that serves to electrically connect isolated microstrips (such as microstrip 102) and secondly electrically connecting all Silver within the circuit to the cathode of the electroplating bath during electroplating. This is usually accomplished by electrically connecting all Silver that is to be electroplated, and connecting a small area of Silver to the cathode of the electroplating bath. The creation of an interconnecting conductive pathways 108 is illustrated in FIG. 2.

FIG. 2 is a flow chart illustrating a prior-art method of manufacturing circuit 100 having Silver microstrip conductors 101 and 102. The process flow begins at step 201 where Silver microstrips 101

and 102, and ground plane 106 are deposited onto substrate 104 and fired. Next, at step 205 interconnecting conductive pathway 108 is deposited onto substrate 104 and fired. As discussed above, interconnecting pathway 108 serves to electrically connect isolated Silver that is to be electroplated so that the connection of a small area of Silver to the cathode of the electroplating bath will serve to connect all Silver in circuit 100 to the cathode of the electroplating bath. At step 210 a plating resist is deposited onto interconnecting conductive pathway 108. This is done in order to prevent Copper from depositing onto interconnecting conductive pathway 108 during the electroplating operation. Next, at step 215 Copper layer 103 is electroplated onto microstrip conductors 101 and 102. As discussed above, this is accomplished by utilizing Copper Sulfate, Sulfuric Acid, and an assortment of organic chemicals to achieve a fine grain finish in the Copper. In particular electroplating takes place by connecting a small area of Silver to the cathode of the electroplating bath and submerging substrate 104 into a Sulfuric Acid/Copper Sulfate bath.

Continuing, at step 220, the resist is removed from interconnecting conductive pathway 108, and at step 225 interconnecting conductive pathway 108 is removed. As discussed above, creation of interconnecting conductive pathways in the manufacture of circuits utilizing microstrip conductors requires added process steps that increase the cost associated with their manufacture. Additionally, due to current density differences across the substrate during electroplating, the protective Copper layer usually has poor uniformity across the substrate. Finally, the electroplating process is environmentally unfriendly since chemicals (such as Copper Sulfate and Sulfuric Acid) utilized in the electroplating process are known to be harmful to the environment.

FIG. 3 is a flow chart illustrating fabrication of a circuit having Silver microstrip conductors in accordance with the preferred embodiment of the present invention. In the preferred embodiment of the present invention the need for temporary interconnecting pathway 108 is eliminated by utilizing an electroless plating process to deposit protective

layer of Copper 103 onto Silver microstrips 101 and 102. The process flow begins at step 301 where substrate 104 is cleaned. In the preferred embodiment of the present invention ceramic substrate 104 is cleaned by immersing substrate 104 in a mixture of an alkaline detergent and water at a temperature of 80 to 90C for 5 minutes followed by a de-ionized (DI) water rinse. Next, at step 303, ground plane 106, and through via 107 are printed onto substrate 104 and fired. In the preferred embodiment of the present invention ground plane 104 comprises a Silver thick film paste, and is printed onto substrate 104 utilizing a stainless steel mesh screen containing the appropriate circuit pattern.

After screen printing, the Silver is fired at a temperature of 905C for 10 minutes. Next, at step 305, Silver microstrips 101 and 102, and through vias are deposited (screen printed) onto upper surface 105 of substrate 104 utilizing the screen printing process and firing process discussed above. Additionally, Silver microstrips 101 and 102 and ground plane 106 comprise pure, dense fired, acid resistant Silver which is chosen because of its ability to tolerate the exposure to the chemicals in both the electroplating and electroless plating processes. The preferred embodiment of the present invention utilizes "7676™" manufactured by Electro Materials Corporation of America (EMCA) as a Silver paste. EMCA can be reached at 160 Commerce Drive, Montgomeryville, PA 18936.

Continuing, at step 307 Copper layer 103 is deposited onto all Silver surfaces via a wet-chemical (immersion into a chemical bath) electroless Copper plating process. In particular, the electroless plating process comprises the steps of:

1: Pre-cleaning all Silver to remove soils and oxides. In the preferred embodiment of the present invention substrate 104 and microstrips 101 and 102 are cleaned by immersing them in an alkaline cleaner. In particular substrate 104 and microstrips 101 and 102 are immersed in 80C "DURAPREP 100™" for 5 minutes, followed by a DI water

rinse. "DURAPREP 100™" is manufactured by Shipley Inc. Shipley can be contacted at 2300 Washington Street, Newton, MA 02162-1469.

2: Utilizing a Palladium Chloride activator to increase plating speeds. While Silver is auto-catalytic in an electroless Copper plating bath, plating will proceed faster if a Palladium Chloride activator is used. In the preferred embodiment of the present invention substrate 104 and microstrips 101 and 102 are immersed in 24C +/- 5C "ACTIVATOR 472™" for 3 minutes followed by a DI rinse. "ACTIVATOR 472™" is manufactured by Shipley Inc.

3: Immersion in an electroless plating bath. In the preferred embodiment of the present invention substrate 104 and microstrips 101 and 102 are immersed in 50C "CIRCUPOSIT ELECTROLESS COPPER 4500™" until 4μm to 8 μm of Copper is deposited onto microstrips 101 and 102. This wet-chemical process usually takes between 1-2 hours. "CIRCUPOSIT ELECTROLESS COPPER 4500™" is manufactured by Shipley Inc.

At step 309 substrate 104 is cleaned by a warm DI water rinse and the logic flow continues to step 311. At step 311 substrate 104 is annealed in order to enhance adhesion of the metals. In the preferred embodiment of the present invention, substrate 104 is placed in an atmosphere of nitrogen at 300-325C for 5-10 minutes.

As is evident, the use of an electroless plating process to plate a protective layer of Copper onto microstrips eliminates the need for temporary interconnecting pathways (pathway 108 in FIG. 1). The elimination of such pathways reduces the cost associated with the manufacture of circuits utilizing microstrip conductors. In addition, the substitution of "CIRCUPOSIT ELECTROLESS COPPER 4500™" for prior art chemicals used in electroplating baths reduces the amount of environmentally unfriendly chemicals utilized during circuit manufacture. Finally, because the deposition of the protective layer of Copper onto the microstrips is accomplished via an electroless plating process, the prior-

art problems with current density/uniformity are eliminated, resulting in a more uniform layer of Copper.

The descriptions of the invention, the specific details, and the drawings mentioned above, are not meant to limit the scope of the present invention. For example, in addition to utilizing a ceramic substrate, other substrates (Printed Circuit Boards for example) may utilize the present invention as well. It is the intent of the inventors that various modifications can be made to the present invention without varying from the spirit and scope of the invention, and it is intended that all such modifications come within the scope of the following claims.

Claims

1. A method for manufacturing a circuit comprising a microstrip conductor, the method comprising the steps of:

depositing a microstrip conductor onto a substrate, wherein the microstrip conductor comprises a first material; and

depositing on the microstrip conductor, a protective layer, wherein the protective layer comprises a second material that is deposited on the microstrip conductor via an electroless plating process.

2. The method of claim 1 wherein the step of depositing the microstrip conductor onto the substrate comprises the step of depositing the microstrip conductor onto a ceramic substrate.

3. The method of claim 1 wherein the first material comprises Silver.

4. The method of claim 3 wherein the Silver comprises a dense-fired, acid-resistant Silver.

5. The method of claim 1 wherein the second material comprises Copper.

6. The method of claim 1 wherein the step of depositing on the microstrip conductor comprises the steps of:

pre-cleaning the first material;

exposing the first material to an activator to increase plating speeds; and

immersing the first material into an electroless plating bath.

7. The method of claim 6 wherein the step of exposing the first material to an activator comprises the step of exposing the first material to a Palladium Chloride activator.

8. A circuit comprising:

a substrate;

a microstrip conductor existing upon the substrate, wherein the microstrip conductor comprises a first material; and

a protective layer existing on the microstrip conductor, wherein the protective layer comprises a second material that is deposited on the microstrip conductor via an electroless plating process.

9. The circuit of claim 8 wherein the substrate is a ceramic substrate.

10. The circuit of claim 8 wherein the first material comprises Silver.

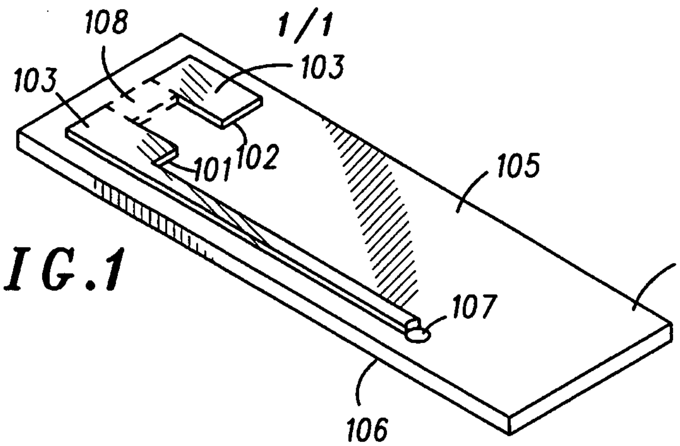

FIG.1

DEPOSIT AND FIRE SILVER MICROSTRIPS AND GROUND PLANE ONTO SUBSTRATE — 201

DEPOSIT AND FIRE INTERCONNECTING CONDUCTIVE PATHWAY ONTO SUBSTRATE — 205

DEPOSIT PLATING RESIST ONTO INTERCONNECTING CONDUCTIVE PATHWAY — 210

ELECTROPLATE COPPER LAYER ONTO MICROSTRIP CONDUCTORS — 215

REMOVE RESIST FROM INTERCONNECTING CONDUCTIVE PATHWAY — 220

REMOVE INTERCONNECTING CONDUCTIVE PATHWAY — 225

FIG.2 —PRIOR ART—

CLEAN SUBSTRATE — 301

PRINT AND FIRE GROUND PLANE AND THROUGH VIA ONTO SUBSTRATE — 303

PRINT AND FIRE SILVER MICROSTRIPS AND THROUGH VIAS ONTO UPPER SURFACE OF SUBSTRATE — 305

ELECTROLESS PLATING — 307
1. PRE-CLEAN ALL SILVER
2. IMERSE SUBSTRATE IN PD/CL ACTIVATOR
3. IMMERSION IN AN ELECTROLESS PLATING BATH

CLEAN SUBSTRATE — 309

ANNEAL — 311

FIG.3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/16875

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B32B 15/04; BO5D 05/12
US CL : 428/621, 632, 673, 674; 427/97, 98, 125, 437
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 428/621, 632, 673, 674; 427/97, 98, 125, 437

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,394,223 A (HALL) 19 July 1983, col. 2, lines 5-8.	1-10
X --- Y	US 4,559,279 A (HONJO et al.) 17 December 1985, col. 2, lines 30-39; col. 3, lines 25-27; col. 4, lines 23-48.	1-6, 8-10 --- 7
X --- Y	US 4,752,555 A (TAKADA et al.) 21 June 1988, col. 2, line 64 - col. 3, line 35.	1-4, 8-10 --- 6-7
A	US 5,043,244 A (CAIRNCROSS et al.) 27 August 1991, col. 8, lines 28-52.	1-10
X,P --- Y,P	US 5,576,053 A (SENDA et al.) 19 November 1996, col. 1, lines 38-43; col. 3, lines 34-61.	1-4, 6-10 --- 5

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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